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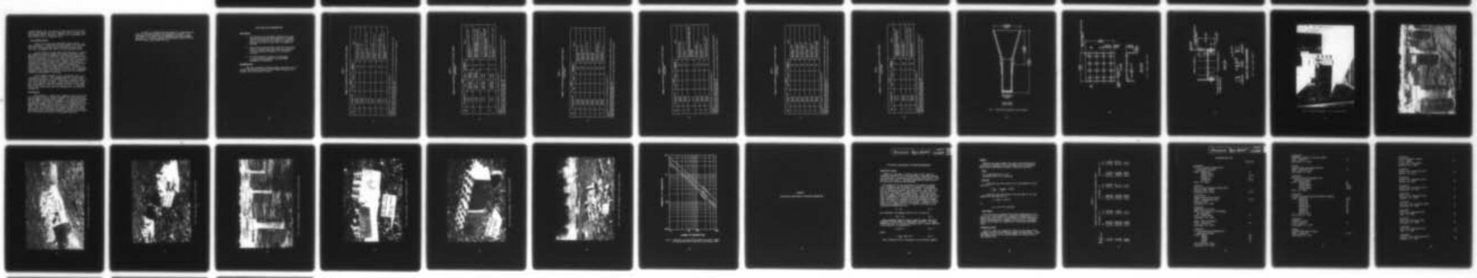

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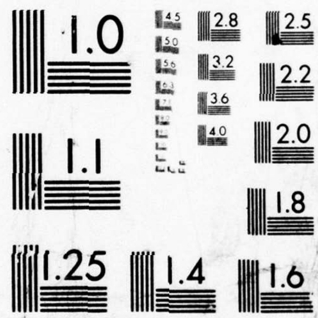

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6 SEPARATION DISTANCE TESTS OF GROUPED FUNNELS FOR 105-MM (M1) PROJECTILES.

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U.S. ARMY ARRADCOM

US ARMY ARMAMENT RESEARCH AND DEVELOPMENT COMMAND
LARGE CALIBER
WEAPON SYSTEMS LABORATORY
DOVER, NEW JERSEY

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20. ABSTRACT (Continue on reverse side if necessary and identify by block number)

Thirty-two tests were conducted to determine the safe clear spacing between conveyor fixture trays containing 16 loaded 105-mm projectile funnels (with Composition B filled risers). These tests simulated the passage of the conveyor trays through the ramp connecting the Funnel Pulling Buildings (E-133 and E-134) and the Riser Melt Building (E-9) at the Lone Star Army Ammunition Plant, Texarkana, Texas. Four of these 32 tests utilized aluminum or steel plate shields. However, further testing with shields was discontinued since an unshielded clearance of 3.66 m (12 ft) between two over

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adjacent trays was found to be safe and will meet production requirements as well. The safety of the 3.66-meter separation was verified by confirmatory testing.

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ACKNOWLEDGEMENTS

The authors wish to express their sincere appreciation to the following for their assistance and guidance during the test program and/or report preparation: Messrs. Irving Forsten, Joseph Marsicovete, Jack Canavan, Peter Skerchock and Curtis Anderson of ARRADCOM, Dover, New Jersey; Captain Edward Bishop, Messrs. Wayne Taylor and Joseph Martinez, and Test Personnel at Yuma Proving Ground, Yuma, Arizona; the 105-mm Design and Development Group at Lone Star Army Ammunition Plant, Texarkana, Texas; and Mr. Norval Dobbs of Ammann & Whitney, Consulting Engineers, New York, New York.

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SUMMARY

Tests described in this report cover one phase of an overall safety engineering program entitled "Safety Engineering in Support of Ammunition Plants" conducted under the guidance of the Manufacturing Technology Division of the Large Caliber Weapons Systems Laboratory, ARRADCOM.

Thirty-two tests were performed to determine the means of safely conveying trays of 105-mm projectile funnels containing Composition B between the Funnel Pulling Buildings (E-133 and E-134), and the Riser Melt Building (E-9) at the Lone Star AAP, Texarkana, Texas.

Sixteen holes were drilled in an aluminum plate in a 4 by 4 matrix to form the tray support for the funnels. The whole assembly representing the tray and the funnels was supported on cinder blocks to achieve the plant operational height of approximately 0.91 meter (3 feet). Four of the 32 tests were conducted to evaluate the effectiveness of aluminum and steel shields. The remaining tests were performed using a simulated conveyor ramp or a tunnel. These tunnels were fabricated at Yuma Proving Ground, Yuma, Arizona, and were 2.44 meters wide by 2.44 meters high by 2.44 meters long (8 feet wide by 8 feet high by 8 feet long). They were constructed from 2 x 2 x 3/16 steel angle frames and were covered with 22-gauge steel corrugated sheeting.

One donor tray and two acceptor trays were used in each test. Initially, the distances between the donor and the two acceptors were varied. For the confirmatory tests, however, both acceptors were placed at a distance of 3.66 meters (12 feet) from the donor. Only one centrally located funnel within the cluster of 16 was initiated using an M6 blasting cap inserted into approximately 55 grams (2 ounces) of Composition C4.

Results of the confirmatory tests indicated that a safe clear separation distance of 3.66 meters (12 feet) would preclude any propagation of explosion with probability of 94, 93 and 89 percent for 90, 95 and 99 percent confidence limits, respectively.

INTRODUCTION

Background

At the present time, an Army-wide expansion program is underway to upgrade existing and to develop new explosive manufacturing and LAP (Load-Assemble-Pack) facilities. Increase in the production cost-effectiveness and improvement in safety records are expected from this effort. As a part of the overall program, the Manufacturing Technology Division of the Large Caliber Weapons Systems Laboratory, ARRADCOM, Dover, New Jersey, under the direction of the Project Manager for Production Base Modernization and Expansion, is engaged in developing safety criteria. The program is labelled as "Safety Engineering in Support of Ammunition Plants". The data developed from this program will be used as the basis for the design of future explosive production installations.

Safe spacing between boxes containing 60 pounds of TNT or Composition B has recently been determined. However, similar information for other explosives and explosive items is still lacking. For example, the facility process for the new 105-mm Projectile Melt/Pour Facility at Lone Star Army Ammunition Plant, Texarkana, Texas, requires that a series of trays be transported on a conveyor within the ramp connecting the Funnel Pulling Buildings (E-133 and E-134) to the Riser Melt Building (E-9). Each tray carries 16 Composition B filled funnels. Since the safe separation between these trays was unknown, a series of tests was performed whereby the required information could be obtained. The results of these tests as well as a description of the overall test series are presented in this report.

Objectives

The primary objective of this program was to either develop means to prevent accidental propagation of detonation from one tray to another with each tray containing approximately 18 kilograms (40 pounds) of Composition B, or to find a safe clear separation distance between two adjoining trays.

The secondary objectives were to see if the new zamac (zinc casting alloy) funnels would enhance propagation of detonation, and to observe if the particular location of a "donor" funnel in a 4 by 4 matrix on a tray had any bearing on the outcome of the propagation of explosion to the other funnels.

Criteria for Confirmatory Tests

Initially, it was intended to perform 25 confirmatory tests with one donor and two acceptors in each test providing 50 observations. These 50 observations with no propagation of explosion in any one observation conform to lower limits of probabilities of no propagation of 93 and 90 percent for confidence levels of 95 and 99 percent, respectively. The upper limit would be 100 percent no propagation of explosion for all confidence levels.

After 47 observations wherein no propagation of explosion took place, an approval from DARCOM and ARMCOM Safety to conclude the test program was sought and granted.

These 47 observations provide 89.5 percent reliability for a 99 percent confidence level as explained in the Test Analysis.

Format and Scope of Report

The main body of this report is divided into three sections. Section 1 contains the background and objectives of the project, whereas Section 2 contains the project test arrangement, results and analysis. The conclusion and recommendations derived from the test results are presented in Section 3.

Since future standards of measurements in the United States will be based upon the SI Units (the International System of Units) rather than the United States System now in use, all measurements presented in this report will conform to those of the SI System. However, for those persons not fully familiar with the SI Units, United States equivalent units of particular test data are presented in parentheses adjacent to the SI unit. A list of units, symbols, and United States conversion factors for SI Units is presented in Appendix A. The method for the development of the statistical evaluation of explosion propagation is presented in the Appendix.

TEST ARRANGEMENT, RESULTS AND ANALYSIS

General

This section describes the test setups used in the test program and evaluates the results of the tests. Identical tests are grouped together. Tests where no shields were used provided sufficient number of observations to merit a quantitative evaluation for predicting the probability of explosion propagation with a certain degree of confidence.

Results of individual tests are listed in Table 1.

Test Arrangement

Funnels and Trays

The cross-section of the riser funnel is shown in Figure 1. The funnels were manufactured using a zinc casting alloy called "zamac". Sixteen of these funnels were supported vertically on a tray in a 4 by 4 matrix. Each funnel contained approximately 1.14 kilograms (2 1/2 pounds) of Composition B. Thus, each tray supported approximately 18 kilograms (40 pounds) of the explosive.

Each tray was fabricated from 6061-T6 aluminum plate 8 millimeters (5/16 inch) thick and 0.53 meter (21 inches) square. Plan and elevations of the tray are illustrated in Figure 2. Sixteen holes were drilled in the tray to support the funnels. When metal shields were used, the shields were attached to the vertical sides of the tray using three 6.35-mm (1/4-inch) diameter bolts.

Details of the shield and its connection to the tray as well as the plan of the test arrangements are illustrated in Figure 3.

Simulated Ramps

The trays containing the funnels were placed on cinder blocks (nominal size 8 inches by 8 inches by 16 inches) to achieve the plant operational height of approximately 0.91 meter (3 feet). One donor tray and two acceptor trays were placed within the confines of a simulated conveyor ramp or a tunnel. These tunnels were fabricated at the Yuma Proving Ground and were 2.44 meters long by 2.44 meters wide by 2.44 meters high (8 feet long by 8 feet wide by 8 feet high). The structural frame was constructed from 2-inch by 2-inch by 3/16-inch steel angles and was covered with a 22-gauge (0.76-mm or 0.03-in) thick corrugated steel sheet.

Figure 4 illustrates a typical test setup with the trays supported on cinder blocks inside the simulated ramp.

Method of Initiation

Only one centrally located funnel within the cluster of 16 was initiated. Initiation was accomplished via an M6 blasting cap inserted into approximately 55 grams (2 ounces) of Composition C-4. A 50-blasting-cap capacity blasting machine was the electrical source which was located at a distance of approximately 300 meters (1,000 feet) away from the test area. At this same location was a bomb-proof observation post which provided protection for the test personnel and a means for observing the tests.

Test Results

Test with Shields

Four tests were performed using either steel or aluminum plate shields. Each test consisted of two acceptor trays separated by a donor tray. In two of these tests, the shields were placed both at the donor and the acceptors; whereas in the remaining two tests, the shields were placed only at the acceptor. Since the ramps were in short supply and it was felt that the tests could be evaluated without them, ramps were not used in this test series.

As listed in Table 1, the shields were utilized in Test Nos. 7 through 10.

Tests Nos. 7 and 8 utilized 9.5-mm (3/8-in) thick 6061-T6 aluminum plate and SAE 1020 steel plate shields, respectively. Shields were located both at the donor and acceptor trays in each test. The clear separation between donor and acceptor trays in each test was 1.83 meters (6 feet).

Figures 5 and 6 illustrate the test setup and post-shot damage, respectively, of Test 7, while Figure 7 shows the damage incurred by the steel shields in Test 8.

Even though there was no propagation in either test, the damage sustained by the funnels indicated that the shields were ineffective and that the donor shields were possibly a source of danger.

In Tests Nos. 9 and 10, the shields were aluminum and steel, respectively. The shields were located only at the acceptor trays (Fig 8). Since the donor shield was not present, damage to the

acceptor funnels was less severe in these tests (Fig 9 and 10) than in the previous two tests. However, since all funnel trays are potential donors, the use of shields only at acceptors will have limited use in a production line.

Test Without Shields

A total of 28 tests were performed without shields. Except for Test No. 31 which had only one acceptor, all individual tests utilized two acceptor trays separated by a donor tray. The tunnel arrangement was used in all tests without shields.

In the initial six tests which were exploratory in nature, the separation distances between the acceptor and donor trays were varied in order to establish a safe clearance between items. Separation distances of 0.93, 1.83, 3.66 and 5.49 meters (3, 6, 12 and 18 feet) were used in the exploratory series. Propagation did not occur in any of these tests. However, the damage incurred by the acceptor funnels at separation distances less than 3.66 meters (12 feet) was severe enough to indicate that, in similar tests, propagation might have occurred. Therefore, for the performance of the confirmatory series of tests, a separation distance of 3.66 meters was selected based upon the acceptable production requirements of the plant.

Typical damage produced in each confirmatory test is illustrated in Figure 11. Even though some holes in the funnels occurred during these tests, the holes were, in general, small in size (9 mm) and small in number. Larger holes did occur in several tests; however, they were usually restricted to one large hole (a maximum of 19 mm) in one funnel per test. As described below, these larger holes were not considered to be a source of propagation.

Test Analysis

Upon breakup of a donor tray, fragments from both the tray and the funnels serve as primary fragments, with the larger number of fragments formed from the funnels. At separation distances of 3.66 meters, the number of fragments which penetrated and/or impacted the acceptor funnels was small. Even though some of the penetrating fragments were relatively large, propagation did not occur. This is attributed to the softness of zamac metal fragments which, upon impact with the acceptor funnels, will deform and thereby lose a considerable amount of energy that would otherwise be transferred directly to the acceptor explosive.

A total of 47 observations were made for a separation distance of 3.66 meters without any propagation explosion. This corresponds to a probability of propagation occurrence between zero and 6, 7.2 and 10.5 percent for confidence limits of 90, 95 and 99 percent, respectively (Fig 12).

CONCLUSIONS AND RECOMMENDATION

Conclusions

1. The initiation of one funnel centrally on a tray containing sixteen 105-mm projectiles of Composition B filled funnels will result in a high order detonation reaction to the entire 16 funnels on the tray.

2. Steel and aluminum shields 9.5 mm (3/8 inch) thick placed on funnel trays were found to be ineffective for separation distances of 1.83 meters (6 feet).

3. A clear separation distance of 3.66 meters (12 feet) between adjacent trays precludes propagation of explosion.

Recommendation

The clear separation distance between adjoining trays of sixteen 105-mm (M1) projectile funnels should be equal to or greater than 3.66 meters (12 feet).

Table 1

Summary of separation distance tests of 105-mm funnels

Test No.	Separation Distance[a] m (ft)	Shields		Propagation of Detonation	Results
		Type	Location		
1	3.66 (12) 3.66 (12)	- -	- -	No No	2F-9 mm (3/8 in) dia. holes[b] 2F-3 mm (1/8 in) dia. holes
2	5.49 (18) 5.49 (18)	- -	- -	No No	1F-3 mm (1/8 in) dia. holes 2F-minor dents
3	3.66 (12) 5.49 (18)	- -	- -	No No	1F-two 13 mm (1/2 in) dia. holes and 1F-13 mm (1/2 in) dia. hole 1F-torn open
4	1.83 (6) 1.83 (6)	- -	- -	No No	4F-9 mm (3/8 in) dia. holes 1F-25 mm (1 in) dia. hole and 3F-9 mm (3/8 dia. holes
5	1.83 (6) 1.83 (6)	- -	- -	No No	4F-numerous 6 mm (1/4 in) dia. holes 4F-9 mm (3/8 in) dia. holes, numerous dents
6	0.91 (3) 3.66 (12)	- -	- -	No No	3F-broken apart, numerous 9 mm holes, acceptor displaced 2.74 m (9 ft) 1F-minor dents

[a] First distance for Acceptor No. 1; second distance for Acceptor No. 2.
[b] Funnels
[c] Some funnels broke apart by impact from the shield; three 76 mm (3 in) dia. holes through shield caused by breakup of donor shield.
[d] Large fragments from donor shield impacted acceptor tray.
[e] Acceptor trays were normally displaced approximately 0.91 m (3 ft) in all other tests conducted at 3.66 m (12 ft) separation.

Table 1

Summary of separation distance tests of 105-mm funnels (continued)

Test No.	Separation Distance[a] m (ft)	Shields Type	Shields Location	Propagation of Detonation	Results
7	1.83 (6)	9 mm (3/8 in) alum. plate	Donor and acceptor	No	Shield ineffective in stopping fragments[c]; holes and dents in funnels
	1.83 (6)	Same as above	Same as above	No	Same as above
8	1.83 (6)	9 mm steel plate	Donor and acceptor	No	Acceptor displaced 38 m (124 ft)[d]; shield ineffective in stopping fragments
	1.83 (6)	Same as above	Same as above	No	Acceptor fixture displaced 33 m (108 ft)[d], 25 mm (1 in) dia. hole through shield into one funnel
9	1.83 (6)	9 mm (3/8 in) alum. plate	Acceptor	No	Two 9 mm (3/8 in) dia. holes through shield
	1.83 (6)	Same as above	Acceptor	No	Six 9 to 13 mm (3/8 to 1/2 in) dia. holes through shield; 1F-13 mm (1/2 in) dia. hole, shield ineffective in stopping fragments
10	1.83 (6)	9 mm (3/8 in) steel plate	Acceptor	No	Minor dents in shield
	1.83 (6)	Same as above	Acceptor	No	Minor dents in shield; shield ineffective in stopping fragments

[a] First distance for Acceptor No. 1; second distance for Acceptor No. 2.

[b] Funnels

[c] Some funnels broke apart by impact from the shield; three 76 mm (3 in) dia. holes through shield caused by breakup of donor shield.

[d] Large fragments from donor shield impacted acceptor tray.

[e] Acceptor trays were normally displaced approximately 0.91 m (3 ft) in all other tests conducted at 3.66 m (12 ft) separation.

Table 1

Summary of separation distance tests of 105-mm funnels
(continued)

Test No.	Separation Distance[a] m (ft)	Shields		Propagation of Detonation	Results
		Type	Location		
11	3.66 (12) 3.66 (12)	- -	- -	No No	2F-6 mm (1/4 in) dia. hole Same as above
12	3.66 (12) 3.66 (12)	- -	- -	No No	2F-6 mm (1/4 in) dia. hole 1F-minor dents
13	3.66 (12) 3.66 (12)	- -	- -	No No	2F-two 13 mm (1/2 in) dia. holes 1F-minor dents
14	3.66 (12) 3.66 (12)	- -	- -	No No	2F-minor dents Same as above
15	3.66 (12) 3.66 (12)	- -	- -	No No	1F-13 mm (1/2 in) dia. hole 2F-three 6 mm (1/4 in) dia. holes
16	3.66 (12) 3.66 (12)	- -	- -	No No	1F-minor dents 1F-6 mm (1/4 in) dia. hole

[a] First distance for Acceptor No. 1; second distance for Acceptor No. 2.
[b] Funnels
[c] Some funnels broke apart by impact from the shield; three 76 mm (3 in) dia. holes through shield caused by breakup of donor shield.
[d] Large fragments from donor shield impacted acceptor tray.
[e] Acceptor trays were normally displaced approximately 0.91 m (3 ft) in all other tests conducted at 3.66 m (12 ft) separation.

Table 1

Summary of separation distance tests of 105-mm funnels
(continued)

Test No.	Separation Distance[a] m (ft)	Shields		Propagation of Detonation	Results
		Type	Location		
17	3.66 (12) 3.66 (12)	- -	- -	No No	1F-19 mm (3/4 in) dia. hole 2F-3 mm (1/8 in) dia. hole
18	3.66 (12) 3.66 (12)	- -	- -	No No	1F-19 mm (3/4 in) dia. hole Minor dents
19	3.65 (12)	-	-	No	Contents of donor tray did not explode due to change in location of primed funnel from a central to an end location
	3.66 (12)	-	-	No	Same as above
20	3.66 (12) 3.66 (12)	- -	- -	No No	Minor dents on funnels 1F-3 mm (1/8 in) dia. hole
21	3.66 (12) 3.66 (12)	- -	- -	No No	Minor dents on funnels Same as above
22	3.66 (12) 3.66 (12)	- -	- -	No No	1F-6 mm x 25 mm (1/4 in x 1 in) hole 1F-two 3 mm (1/8 in) dia. holes

[a] First distance for Acceptor No. 1; second distance for Acceptor No. 2.
[b] Funnels
[c] Some funnels broke apart by impact from the shield; three 76 mm (3 in) dia. holes through shield caused by breakup of donor shield.
[d] Large fragments from donor shield impacted acceptor tray.
[e] Acceptor trays were normally displaced approximately 0.91 m (3 ft) in all other tests conducted at 3.66 m (12 ft) separation.

Table 1

Summary of separation distance tests of 105-mm funnels
(continued)

Test No.	Separation Distance[a] m (ft)	Shields		Propagation of Detonation	Results
		Type	Location		
23	3.66 (12) 3.66 (12)	- -	- -	No No	Minor dents on funnels Same as above
24	3.66 (12) 3.66 (12)	- -	- -	No No	1F-25 mm (1 in) dia. hole Minor dents on funnels
25	3.66 (12) 3.66 (12)	- -	- -	No No	1F-13 mm (12 in) dia. hole Minor dents on funnels
26	3.66 (12) 3.66 (12)	- -	- -	No No	1F-3 mm (1/8 in) dia. hole Same as above
27	3.66 (12) 3.66 (12)	- -	- -	No No	1F-25 mm (1 in) dia. hole Minor dents on funnels
28	3.66 (12) 3.66 (12)	- -	- -	No No	2F-2 mm (1/16 in) dia. holes 2F-6 mm (1/4 in) dia. holes

[a] First distance for Acceptor No. 1; second distance for Acceptor No. 2.
[b] Funnels
[c] Some funnels broke apart by impact from the shield; three 76 mm (3 in) dia. holes through shield caused by breakup of donor shield.
[d] Large fragments from donor shield impacted acceptor tray.
[e] Acceptor trays were normally displaced approximately 0.91 m (3 ft) in all other tests conducted at 3.66 m (12 ft) separation.

Table 1

Summary of separation distance tests of 105-mm funnels
(concluded)

Test No.	Separation Distance[a] m (ft)	Shields		Propagation of Detonation	Results
		Type	Location		
29	3.66 (12)	-	-	No	3F-3 mm to 13 mm (1/8 in to 1/2 in) dia. holes; acceptor tray displaced 3.66 m (12 ft)[e]
	3.66 (12)	-	-	No	1F-3 mm (1/8 in) dia. hole; acceptor tray displaced 5.49 m (18)[e]
30	3.66 (12)	-	-	No	1F-2 mm (1/16 in) dia. hole
	3.66 (12)	-	-	No	Minor dents on funnels
31	3.66 (12)	-	-	No	1F-25 mm (1 in) dia. hole, minor dents on funnels
32	3.66 (12)	-	-	No	2F-3 mm and 6 mm (1/8 in and 1/4 in) dia. holes
	3.66 (12)	-	-	No	Minor dents on funnels

[a] First distance for Acceptor No. 1; second distance for Acceptor No. 2.
[b] Funnels
[c] Some funnels broke apart by impact from the shield; three 76 mm (3 in) dia. holes through shield caused by breakup of donor shield.
[d] Large fragments from donor shield impacted acceptor tray.
[e] Acceptor trays were normally displaced approximately 0.91 m (3 ft) in all other tests conducted at 3.66 m (12 ft) separation.

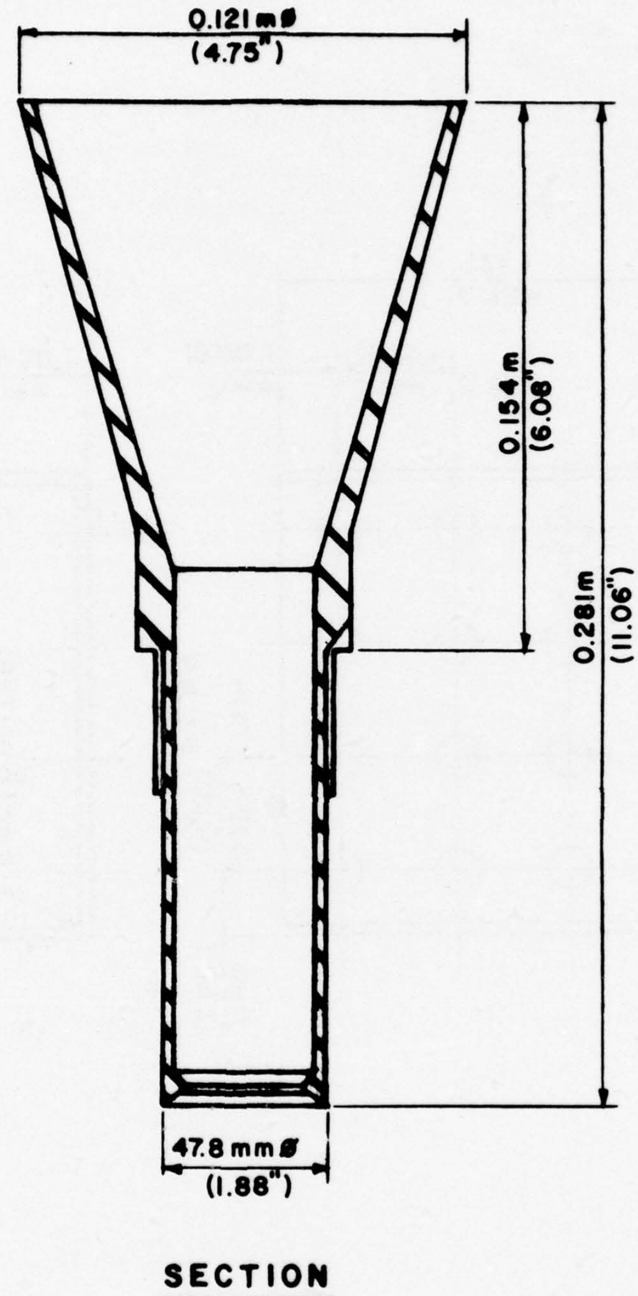

Fig 1 105-mm (M1) projectile riser funnel.

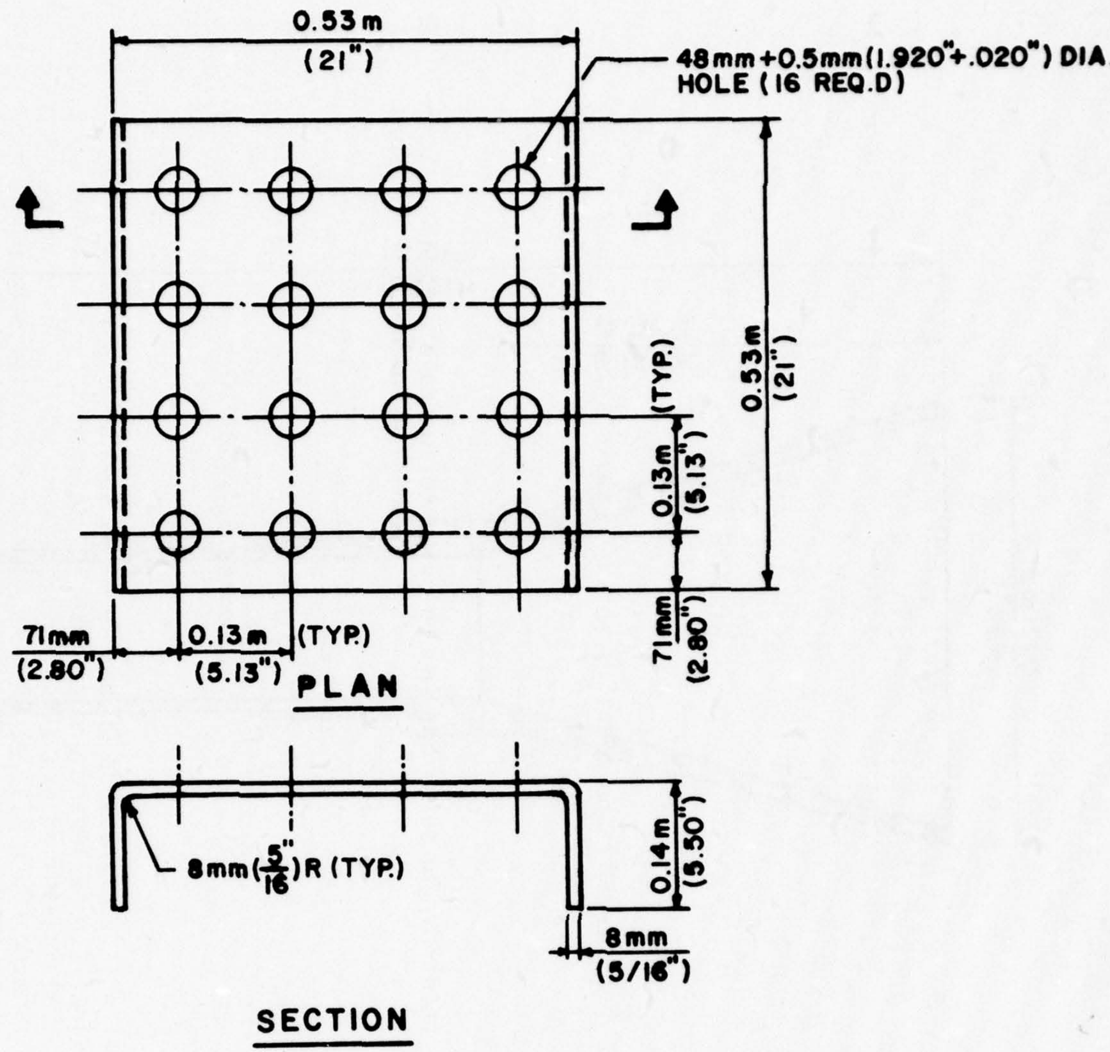

Fig 2 Funnel support tray.

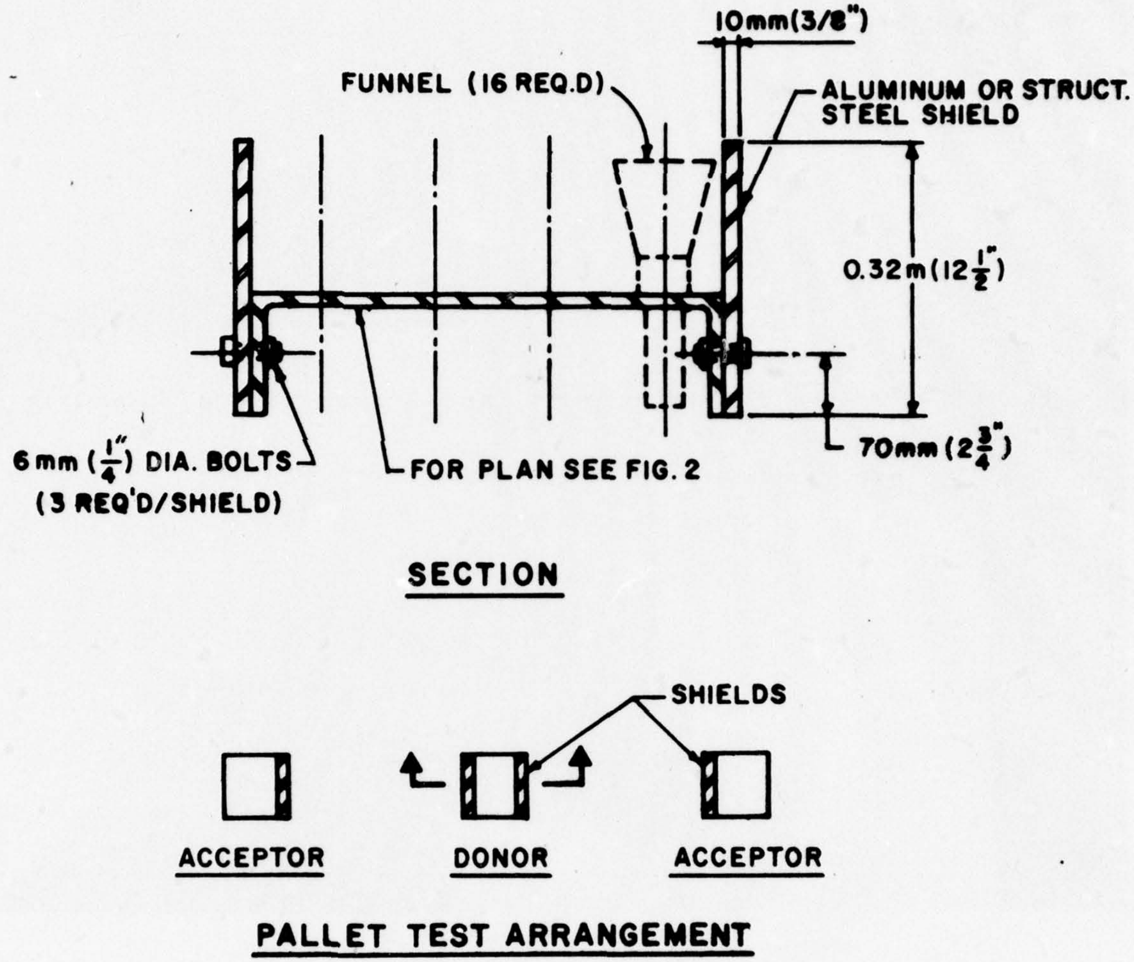

Fig 3 Blast shield details.

Fig 4 Typical arrangement - test without shields.

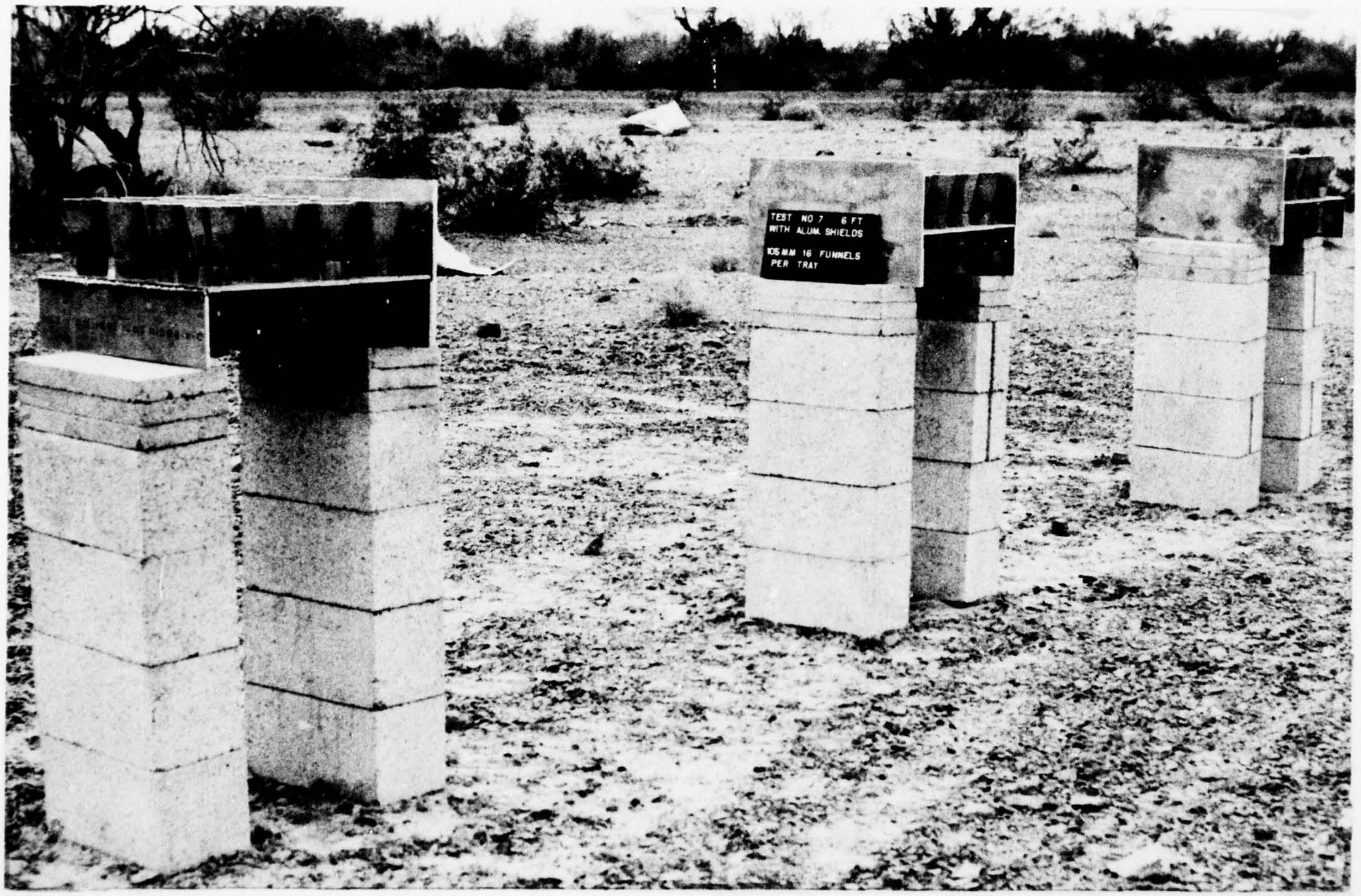

Fig 5 Typical arrangement - test with shields.

Fig 6 Post shot damage - Test 7 (steel shields).

Fig 7 Post shot damage - Test 8 (steel shields).

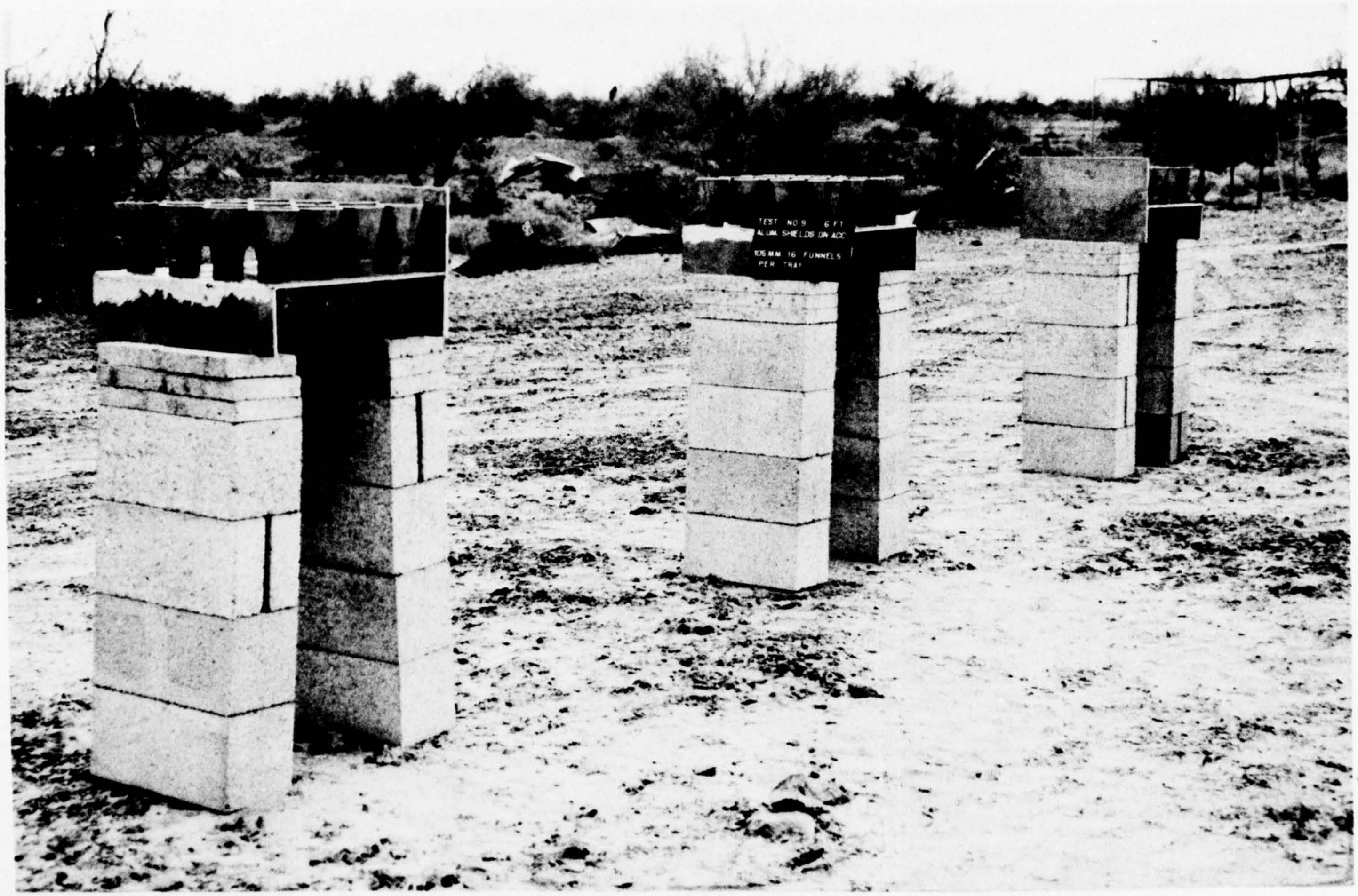

Fig 8 Typical arrangement - tests with shields at acceptors only.

Fig 9 Post shot damage - Test 9 (aluminum shields).

Fig 10 Post shot damage - Test 10 (aluminum shields).

Fig 11 Typical post shot damage for tests without shields.

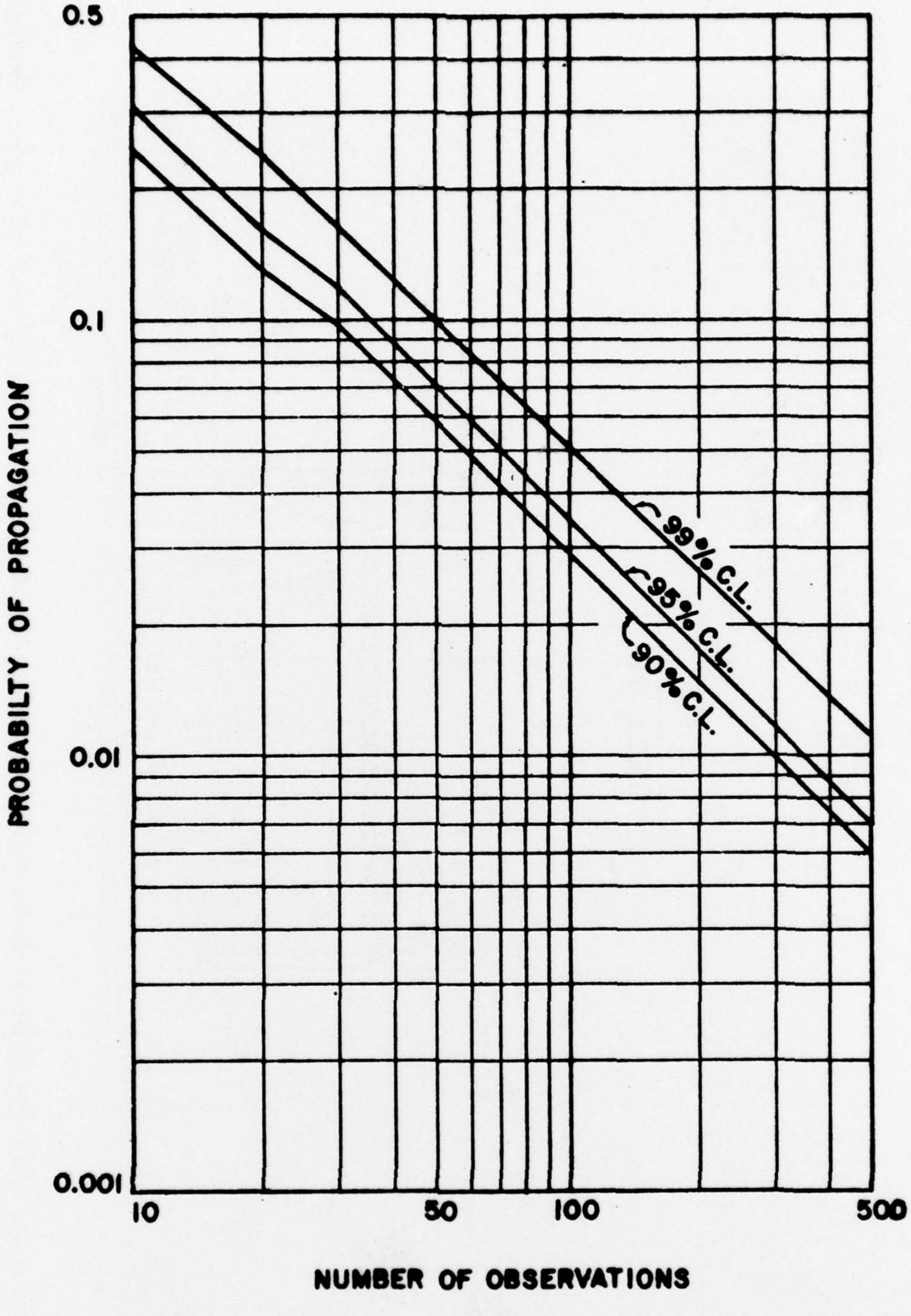

Fig 12 Variation of propagation probability versus number of observations as a function of confidence level.

APPENDIX

STATISTICAL EVALUATION OF EXPLOSION PROPAGATION

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STATISTICAL EVALUATION OF EXPLOSION PROPAGATION

Statistical Theory

Attempt has been made in the main body of this report to evaluate the possibility of the occurrence of explosion propagation based upon a statistical analysis of the test results. This section of the report is devoted to mathematical means by which the statistical analysis was performed.

The probability of the occurrence of an explosion propagation is dependent upon the degree of certainty or confidence level involved and has upper and lower limits. The lower limit for all confidence levels is zero, whereas the upper limit is a function of the number of observations or, in this particular case, the number of acceptor items tested. Since each observation is independent of the others and each observation has a constant probability of a reaction occurrence (explosion propagation), the number of reactions (x) in a given number of observations (n) will have a binomial distribution. Therefore, the estimate of the probability (p) of a reaction occurrence can be represented mathematically by:

$$p = x/n \qquad \text{Eq. 1}$$

and, therefore, the expected value of (x) is given by:

$$E(x) = np \qquad \text{Eq. 2}$$

Each confidence level will have a specific upper limit (p_2) depending upon the number of observations involved. The upper probability limit for a given confidence level α, when a reaction is not observed, is expressed as:

$$(1-p_2)^n = \varepsilon \qquad \text{Eq. 3}$$

where,

$$\varepsilon = \frac{1-\alpha}{2} \text{ and } \alpha<1.0 \qquad \text{Eq. 4}$$

Use of equation (3) is illustrated in the following example:

Example

Determine the upper probability limit of the occurrence of an explosion propagation for a confidence level of 95 percent based upon 30 observations without a reaction occurrence.

Given

No. of Observations (n) = 30
Confidence level (α) = 95 percent

Solution

1. Substitute the given value of (α) into equation (4) and solve for ε;

$$\varepsilon = \frac{1-\alpha}{2} = \frac{1-0.95}{2} = 0.025$$

2. Substitute the given value of (n) and value of (ε) into equation (3) and solve for p_2

$$\varepsilon = 0.025 = (1-p_2)^{30}$$

or,

$$p_2 = 0.116 \text{ (11.6 percent)}$$

Conclusions

For a 95 percent confidence level and 30 observations, the true value of the probability of explosion propagation will fall between zero and 0.116; or statistically it can be interpreted that in 30 observations a maximum of 3.48 (=0.116 x 30) observations could result in a reaction for a 95 percent confidence level.

Probability Table

Table A-1 shows the probability limits and the range of the expected value E(x) for different numbers of observations. Three confidence limits, 90, 95, and 99 percent, are used to derive the probabilities.

Table A-1

Probabilities of Propagation for Various Confidence Limits

No. of Observations	90 percent C.L.		95 percent C.L.		99 percent C.L.	
n	p_2	E(x)	p_2	E(x)	p_2	E(x)
10	0.259	2.59	0.308	3.08	0.411	4.11
20	0.131	2.62	0.168	3.36	0.233	4.66
30	0.095	2.85	0.116	3.48	0.162	4.86
40	0.072	2.88	0.088	3.52	0.124	4.96
50	0.058	2.9	0.071	3.55	0.101	5.05
60	0.049	2.92	0.060	3.6	0.085	5.10
80	0.037	2.96	0.045	3.6	0.064	5.12
100	0.030	3.0	0.036	3.6	0.052	5.2
200	0.015	3.0	0.018	3.6	0.026	5.2
300	0.010	3.0	0.012	3.6	0.018	5.4
500	0.006	3.0	0.007	3.5	0.011	5.5

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